

FINAL REPORT  
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Boron Abundances in A and B-type Stars

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Prepared for the  
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## Introduction

NAG5-2484 was awarded to support analysis of appropriate IUE archival spectra in an attempt to determine the boron abundances of A and B-type stars from the B II 1362 Å resonance line. A paper was in press describing the results of our analysis; the abstract of that paper is attached to this report.

## Analysis

The IUE spectra were analysed by the P.I. and Dr. Kim Venn (formerly of UT Austin, then a postdoctoral fellow at the University of Munich, Germany) with assistance also from Dr. M Lemke (formerly a postdoc. at UT Austin, then a research associate at the University of Cambridge, England). The method of spectrum synthesis was adopted.

## IUE Spectra

High resolution, ultraviolet spectra were gathered from the IUE archives. For each star, the archives were surveyed for SWP spectra; these spectra were extracted and coadded in order to achieve as high a signal-to-noise as possible. Our preference was for spectra taken with the small aperture since these tended to have a higher signal-to-noise per exposure; however, when few of these were available, and if there were several spectra taken with the large aperture, than we coadded these. Before coadding, the spectra were shifted so that the spectral features lined up as well as possible around 1362 Å; spectra were typically shifted by less than 0.2 pixels. Of all the IUE spectra examined only 8 stars proved to have a combined signal-to-noise ( $\geq 15$ ) that was deemed adequate to determine the boron abundance or to provide an interesting upper limit.

## Results and Conclusions

Boron abundances were obtained for three stars and upper limits for five additional stars. The IUE spectra for the many other B stars that we examined proved to have too low a signal-to-noise ratio for a useful synthesis.

Conclusions concerning the role of boron as an indicator of the evolutionary status of A and B type stars must be tempered by the realization that the B II 1362 Å line is not unblended. There is a possibility of unidentified lines contributing to the absorption feature that we attribute to B II. This qualification, however, does not preclude us from drawing several useful conclusions.

A meteoritic/solar boron abundance,  $\log \epsilon(\text{B}) = 2.8$ , results in a 1362 B II feature that is too strong to match the observed spectrum of all our program stars. In particular, the predicted feature fails to match the observed one for the

two main sequence stars that appear unmixed according to their low nitrogen abundances. The maximum boron abundance from our small sample is about 0.8 dex less than the meteoritic/solar value. The correct interpretation of this difference is as yet unclear. It may represent a true (natal) reduction, as seems apparent for C, N, and O from the recent analyses of B stars cited above; infall of primordial matter could accomplish these overall reductions. Mass loss by main sequence B stars can also lead to a reduced initial boron abundance if the cumulative loss exceeds about 2 per cent of the initial mass. Unless the extreme outer layers are unexpectedly convective, mass loss will not lead to a steady reduction of the surface boron abundance but rather provide for an abrupt decrease as the layers thoroughly depleted of boron are exposed. Alternatively, the boron abundances from LTE analyses of the spectra of these warm and hot stars may be an underestimate of the true abundance. This possibility deserves to be tested by non-LTE calculations that are now feasible, although BHs observation that the derived boron abundances are independent of  $T_{\text{eff}}$  over the entire range (9000 to 25000 K) would seem to suggest that non-LTE effects are small.

Whatever the true initial boron abundance of these stars, and despite the possibility of non-LTE effects, it seems clear that boron is depleted in some stars, and especially in the supergiants. There is a suspicion that the nitrogen and boron abundances are anticorrelated, as would be expected from mixing between the H-burning and outer stellar layers. The magnitude of the nitrogen enrichment (0.3 dex or so) and the boron depletion (a factor of  $\sim 100$ ) are roughly consistent with predictions of the first dredge-up. If, as we suspect, a residue of boron is present in the A-type supergiants, we may exclude a scenario in which mixing occurs continuously between the surface and the deep layers operating the N-enriching CN-cycle.

Further exploitation of the B II 1362 Å line as an indicator of the evolutionary status of A and B-type stars will require a larger stellar sample to be observed to the higher S/N ratios attainable with HST. Time has been granted to this project. A parallel effort to improve the completeness of the required atomic data should be undertaken. Calculations have been made to assess the magnitude of the non-LTE effects.

## Publication

The following paper was published in *Astronomy and Astrophysics*, vol. 307, p. 307, 1996: The Abundance of Boron in Evolved A- and B- Type Stars, Kim A. Venn, David L. Lambert, and M. Lemke.

# ABSTRACT

Boron abundances in A- and B-type stars may be a successful way to track evolutionary effects in these hot stars. The light elements - Li, Be, and B - are tracers of exposure to temperatures more moderate than those in which the H- burning CN-cycle operates. Thus, any exposure of surface stellar layers to deeper layers will affect these light element abundances. Li and Be are used in this role in investigations of evolutionary processes in cool stars, but are not observable in hotter stars. An investigation of boron, however, is possible through the B II 1362 Å resonance line.

We have gathered high resolution spectra from the IUE database of A- and B-type stars near  $10 M_{\odot}$  for which nitrogen abundances have been determined (by Gies & Lambert 1992 and Venn 1995). The B II 1362 Å line is blended throughout; the temperature range of this program, requiring spectrum syntheses to recover the boron abundances. For no star could we synthesize the 1362 Å region using the meteoritic/solar boron abundance of  $\log \epsilon(B) = 2.88$  (Anders & Grevesse 1989); a lower boron abundance was necessary which may reflect evolutionary effects (e.g., mass loss or mixing near the main-sequence), the natal composition of the star forming regions, or a systematic error in the analyses (e.g., non-LTE effects). Regardless of the initial boron abundance, and despite the possibility of non-LTE effects, it seems clear that boron is severely depleted in some stars. It may be that the nitrogen and boron abundances are anticorrelated, as would be expected from mixing between the H-burning and outer stellar layers. If, as we suspect, a residue of boron is present in the A-type supergiants, we may exclude a scenario in which mixing occurs continuously between the surface and the deep layers operating the CN-cycle. Further exploitation of the B II 1362 Å line as an indicator of the evolutionary status of A- and B-type stars will require a larger stellar sample to be observed with higher signal-to-noise as attainable with the *Hubble Space Telescope*.